Designing Mobile Learning Experiences

Giasemi Vavoula[1] and Charalampos Karagiannidis[2]

[1] Institute of Educational Technology, The Open University, UK
g.vavoula@open.ac.uk
[2] University of the Aegean, Department of Cultural Technology and Communication, Mytilini, Lesvos Island, Greece
karagian@acm.org

Abstract. This paper reviews existing applications of mobile learning, and discusses some design issues for the development of mobile learning experiences.

1 Introduction

The emergence of the knowledge society poses new requirements for education and training: the knowledge-based economy requires a flexible, very well-trained workforce; and the citizens of the information society need to be continuously (re)trained in order to remain competitive within this workforce and to fully exploit the learning opportunities offered by the knowledge society for their personal development, fulfillment and enjoyment.

The rapid evolution of learning technologies – exploiting the respective developments in information and communication technologies (ICT) – create numerous new opportunities for meeting these requirements: web-based learning environments (learning management systems, learning content management systems, etc) deliver life-long education and training applications and services to *anyone, anytime, anyplace*. However, most of these applications realize a learning model that is rather "traditional" in nature: it is based on the notion of one (or more) tutors, who help learners acquire a specific body of knowledge (through learning material, learning activities, etc), which can be measured through specific assessment methods. Such a model does not fit instances of learning that occur in the process of specific problem solving in the course of everyday life: "When the person's central concern is a task or decision, he will not be very interested in learning a complete body of subject matter. Instead, he will want just the knowledge and skill that will be useful to him in dealing with the particular responsibility of the moment" ([1], pp. 51).

Recent developments in ICT, and especially in mobile and wireless technologies, facilitate the departure from traditional learning models, since learning can be easily "carried", and even embedded, into our everyday environment. The exploitation of this potential brings about a new era for learning: just-in-time, just-enough, on-demand personalized learning experiences, seamlessly integrated within our everyday activities.

This is the context where the paradigm of mobile learning is emerging. In the following section we present an overview of the current state-of-the-art in learning

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technologies and identify the gap that the emerging paradigm of mobile learning aims to fill in. We then introduce mobile learning and present a brief overview of the area in section 3. In section 4 we analyze the dimensions of, and discuss some design issues for mobile learning systems.

2 The Present: State-of-the-Art in Learning Technologies

Learning technologies[1] are attracting increasing interest worldwide, since they can meet the requirements of the knowledge society and knowledge-based economy for high-quality life-long learning. Over the past decades, a number of applications and services have been made available out of these efforts, reflecting, or even driving a paradigm shift in technology-enhanced learning: from computer-assisted learning, to web-based learning, to mobile learning.

Over the last decade, a major transformation has taken place due to the wide adoption of the internet. The main drivers for this transformation can be summarized as follows:[2]

- *demand*: rapid obsolescence of knowledge and training; need for just-in-time training delivery; search for cost-effective ways to meet learning needs of a globally distributed workforce; skills gap and demographic changes which drive the need for new learning models; demand for flexible access to lifelong learning; etc;
- *supply*: internet access is becoming standard at work and at home; advances in digital technologies enable the creation of interactive, media-rich content; increasing bandwidth and better delivery platforms make e-learning more attractive; a growing selection of high-quality e-learning products and services are made available; emerging technology standards facilitate compatibility and reusability of e-learning products; etc.

As a result, the interest in learning technologies in the past few years has turned mainly into:

- the *development* of learning *material*, *activities* and *software*, which is of high-quality, exploiting multimedia, interactive, immersive and mobile technologies and
- the *delivery* and *management* of such material, activities and software.

Figure 1 depicts the idea of learning content management systems (LCMSs), as they reflect the development, management and use stages of the learning technology development cycle. Re-usable learning objects ("any digital resource that can be reused to support learning"), learning activities, software, etc, are created by instructional designers, subject experts, or even learners and are published within a common repository, together with their description (which is based on a common format, e.g. through learning technologies specifications and standards, or following the specific conventions of a learning community). Learners and teachers can search this repository to retrieve, access and share learning objects according to their profile

[1] We use this term to refer to applications of ICT for learning.
[2] Source: SRI Consulting and WR Hambrecht + Co.

and learning objectives (which can also be described through a common format) and annotate and augment them with personal notes, ideas and interpretations and share them back with other learners and the community.

LCMSs offer a number of advantages, including: re-usability of learning material (facilitating the development of economies of scale), personalized access to learning material, just-in-time, on-demand and just-enough learning.

These developments facilitate the departure from a number of constraints, relating to time and place, as the learning resources become available at all times, outside classrooms or libraries. However, the current state-of-the-art still realizes a learning model which is rather "traditional" in nature: learners access a common repository to acquire a body of knowledge, which can be assessed against specific measures. This misses out the conversational and situational nature of learning and knowledge.

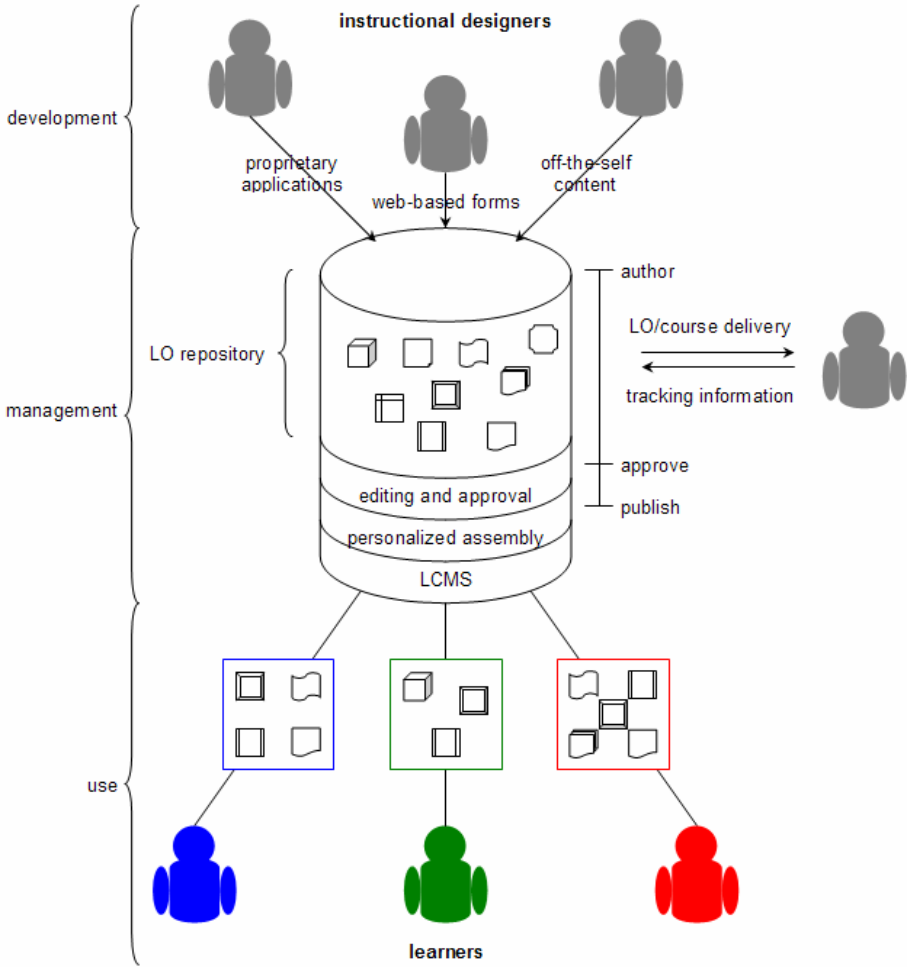

Fig. 1. Learning Content Management Systems (adopted from [2])

Moreover, a number of constraints are not yet overcome: learners need to be in specific places where they have internet access through a desktop or laptop machine.

The next section describes mobile learning, as the emerging paradigm that bares the potential to overcome some of these constraints: learners can learn anytime, anywhere, accessing location and context-specific learning resources as the need arises, in continuous contact and collaboration with fellow learners and tutors.

3 The Emerging Paradigm: Mobile Learning

Mobile learning is usually defined as learning that takes place via wireless devices, such as mobile phones, personal digital assistants, tablet computers, etc. That is, in most definitions encountered in the literature, it is only the employment of specific types of technology that seems to differentiate mobile learning from other forms of learning. However, when considering mobility from the learner's point of view, it can be argued that mobile learning can take place everywhere: pupils can revise for exams on the bus to school, doctors can update their medical knowledge while on hospital rounds, language students can improve their language skills while traveling abroad. In this context, a definition of mobile learning should therefore be widened to include any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies [3].

There are a number of reasons which make mobile technologies and devices attractive for learning, including: palmtops are relatively inexpensive, compared with full-sized desktop or laptop computers; they offer the possibility of ubiquitous computing; they facilitate access to information and promote the development of information literacy; they offer the possibility of collaborative learning and independent learning [3].

During the past few years, mobile devices and technologies have become mainstream and, as a result, a number of prototype learning applications have been deployed and tested in different contexts (extensive reviews are included in [3], [4], [5], [6]). Table 1 presents a categorization of such applications according to their underlying learning model, based on [5].

The above description demonstrates that learning and teaching with mobile technologies is beginning to make a breakthrough from small-scale pilots to institution-wide implementations. A number of key issues need to be taken into account in the development of these implementations, which can be summarized as follows:

- *context*: gathering and utilizing contextual information may clash with the learner's wish for anonymity and privacy;
- *mobility*: the ability to link to activities in the outside world also provides students with the capability to "escape" the classroom and engage in activities that do not correspond with either the teacher's agenda or the curriculum;
- *learning over time*: effective tools are needed for the recording, organization and retrieval of (mobile) learning experiences;

Table 1. Review of Mobile Technologies for Learning (adopted from [5])

Theme	Key Theorists	Activities	Example Systems
Behaviorist learning	Skinner, Pavlov	– drill and feedback – classroom response systems	– Skills Arena: a mathematics video game where drills in addition and subtraction are presented as a game with advanced scoring and recordkeeping, character creation and variable difficulty level – BBC Bitesize: provides revision materials via mobile phones; it has been running since 2003 and has proved to be very popular (over 650,000 GCSE students, as well as a number of curious adult learners) – m-phones for language learning: SMS is used as part of an English language course, where students receive frequent vocabulary messages (which also act as reminders to revise) – classroom response systems: e.g. Classtalk which engages students in communication with the classroom, for articulating and presenting their ideas
Constructivist learning	Piaget, Bruner, Papert	– participatory simulations	– the virus game: each student wears a badge-tag which shows whether they are "infected"; students can watch the "spread of the disease", through their communication – savannah: students play the role of lions roaming in the wild in an area 100m x 50m; each student carries a PDA that gives them a "window" into the gameworld, displaying content and actions that were appropriate to their current location and what was going on in the rest of the game – environmental detectives: a scenario was built around a spill of a toxin; students develop a suitable remediation plan, assisted by their PDAs which allow them virtual activities based on their virtual location
Situated learning	Lave, Brown	– problem and case-based learning – context awareness	– ambient wood: integrates physical and digital interaction; digital information is coupled with novel arrangements of electronically-embedded physical objects; a series of activities are designed around the topic of habitats, focusing on the plants and animals in the different habitats of woodland and the relationships between them – natural science learning: a butterfly-watching system; a database of different butterfly species is used with a content-based image retrieval system; students visit a butterfly farm, take photographs of the butterflies and query the database for possible matches

Table 1. Review of Mobile Technologies for Learning (adopted from [5]) continued

Theme	Key Theorists	Activities	Example Systems
Situated learning (continued)	Lave, Brown	– problem and case-based learning – context awareness	– Tate modern: allows visitors to view video and still images, listen to expert commentary and reflect on their experience by answering questions or mixing a collection of sound clips to create their own soundtrack for an artwork; the wireless network is location-sensitive, which means that users do not have to search out the information – MOBIlearn: context-awareness is being explored, not just as a way to deliver appropriate content, but to enable appropriate actions and activities, including interactions with other learners in the same or similar contexts
Collaborative learning	Vygotsky	– mobile computer-supported collaborative learning (MCSCL)	– MCSCL: activities are distributed through the teacher's hand-held device; the teacher downloads the activity from the project website and then transmits the activity to the students; the students are automatically assigned to collaborative groups; upon completion of the activity, the teacher's Pocket PC collects the students work, which can then be downloaded to the school's PC for analysis
Informal and lifelong learning	Eraut	– supporting intentional and accidental learning episodes	– m-learn: mobile technology to teach basic literacy and numeracy skills; custom content was created, for example an urban soap opera about two characters moving into a flat for the first time to help with language and provide advice about how to set up a home – breast cancer care: delivers personalized education of breast cancer patients; the users can query specific subject knowledge bases through a content specialist, to gain the information they need
Learning and teaching support	n/a	– personal organization – support for administrative duties (e.g. attendance)	– student learning organizer: an integrated suite of software tools enabling students to create, delete and view timetable events and deadlines, as well as download course material packages – support for teachers and administrators: managing teachers' workloads and supporting teaching and learning – SMS supports computing students at risk: develops, delivers and evaluates blending learning opportunities that exploit SMS, WAP and VLE technologies; students use SMS text messaging, receive noticeboard information such as room changes, appointments, feedback and exam tips via SMS

- *informality*: students may abandon their use of certain technologies if they perceive their social networks to be under attack; and
- *ownership*: students want to own and control their personal technology, but this presents a challenge when they bring it in to the classroom [5].

The following section scrutinizes the process of designing mobile learning applications and lists related, more specific, design issues that need to be addressed.

4 Mobile Learning Design Issues

A number of issues need to be taken into account when designing mobile learning applications. For example, the rapid advancements in mobile technology, the general incompatibility between devices, operating systems and applications, and the limited resources in relation to desktop technologies, make the choice of mobile technologies and infrastructures a very important decision.

In the following we examine the main dimensions of mobile learning systems in relation to (currently available) technologies, and suggest corresponding checklists to inform and evaluate design choices.

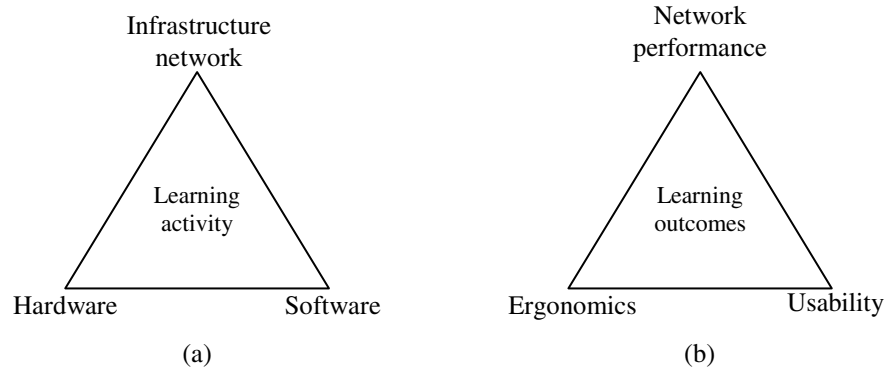

Fig. 2. Dimensions for the (a) design and (b) evaluation of mobile learning systems

As Figure 2 depicts, the choices of infrastructure networks, hardware and software are interdependent and intertwined with the design of the learning activities.

The design of the learning activities for mobile learning is governed by the same principles as the design of any other technology based learning activities, and the choice of the type of activity to implement has to be guided by the learning objectives. What the designer needs to bear in mind is that they design for the learning, not for the technology. The use of (mobile) technology is not the objective; rather, it is a means to enable activities that were otherwise not possible, or to increase the benefits for the learner(s). It is possible that the use of mobile technologies is suitable for only a part of the learning activity, whereas other parts are better supported by other technologies – or even by no technology at all.

The infrastructure network component includes decisions about the selection of communication networks and, in the case of location-aware applications, the selection

of positioning systems. The available communication networks include satellites, mobile telephony, wireless local networks, personal ad-hoc networks, etc. The selection of an infrastructure network is informed by the number of users, the need for range, connectivity and data access, the time and place of use, possible interference with other devices, security requirements, the costs to the provider and/or the user and the network configuration.

The available positioning technologies include infrared, Bluetooth, WiFi and Ultra Wide Band, radio frequency systems such as GPS and RFID and hybrid radio frequency systems that make use of ultrasound (for a concise review see [7]). The selection of a positioning technology is informed by the requirements for precision (for example, the requirements are looser for outdoors than indoors applications), the need for real-time positioning, and whether the location tracking is automatic (e.g. the user is continuously tracked) or user-initiated (e.g. the user deliberately declares their position using, for example, RFID tags/readers).

With regard to the hardware, there is a wide range of mobile devices to choose from including laptops/notebooks, tablet computers, personal digital assistants (PDAs) and smart phones. The selection of a device depends on the requirements for processing power, battery life, robustness and ergonomics factors (for example, whether the user has only one or both hands available, if they are moving or standing still, the weight they can bear, environmental factors such as temperature and noise, etc.). Another issue that needs to be taken into account is the management of the hardware, especially in the case where it is provided by an educational institution as part of a course: are the devices for individual or for group use? Can the learners take the devices home? Who is responsible for damage? Etc.

Related to hardware are also the sensors and probes often used in context-aware mobile learning applications [8]. Context-awareness in mobile learning enables the delivery of context-specific content, options and services [9]. Available context attribute sensors include environmental sensors for measuring, for example, light, sound, atmospheric elements, pressure, humidity, precipitation and air temperature; activity sensors for recognizing, for example, body and eye movement, touch and limb orientation; and body sensors for measuring, for example, heart rate, blood pressure and brain activity (ECG). The type of sensors to use depends on the context attributes that are judged relevant to the learning experience.

With regard to the software a great challenge lies in the design of the user interface, the help system and the interaction. The typically small screen size and limited processing power limit designer choices and resources. Example interfaces are map-, menu-, voice-, text-based – and many more. Nielsen's usability heuristics [10] offer a good summary of the desired attributes of user interfaces.

The help system is there to provide easy recovery from errors and faults, to assist in the performance of all functions (trivial or not), to adapt to the user and their actions. Possible components to incorporate in a help system include tutorials, FAQ lists, troubleshooting guides, hypertext documentation, etc. Issues to consider are the accuracy and completeness of the content, the appropriateness of the structure, the appearance, and the extent to which the help system adapts to the user.

To design the interactions, we need to study the users, their activities and their environment in relation to the learning activity. For example, the use 'on the go'

Table 2. Designer checklists for components of mobile learning systems

	Component	Example choices	Checklist	Technical Evaluation
Activity	*Learning activity*	Drill-and-practice, problem-based learning, classroom response, etc	Learning objectives	Relative learner performance
Infrastructure	*Communications Network*	Satellites, mobile telephony, WLAN, personal ad-hoc, etc	Number of users, Range coverage, Connectivity and data access, Time and place of use, Interference, Security, Costs, Configuration, Management	Reliability, Security, Quality of service, Seamlessness
	Positioning System	Infrared, Bluetooth, WiFi, Ultra Wide Band, RF (GPS, RFID), Hybrid RF, etc	Precision, Real-time, Automatic vs. user-initiated	
Hardware	*Devices*	Laptops/notebooks, tablets, PDAs, smart phones, etc	Processing power, Battery life, Robustness, Ergonomics	Ergonomics, Robustness, Performance, Accuracy, Reliability, Unobtrusiveness
	Sensors and probes	Environmental sensors (sensors for light, wind, CO, Radon, sound, pressure, humidity, precipitation, air temperature, smoke), Activity sensors (movement, touch, accelerometers, eye-trackers, skin conductance, limb orientation), Body sensors (heart rate, blood pressure, blood composition, exhaled air composition, ECG, EEG), etc	Required context attributes	Ergonomics, Robustness, Performance, Accuracy, Reliability, Unobtrusiveness
Software	*Interface*	Map-based, menus, voice, textual, etc	System status visibility, match with real world, user control, consistency and standards, error prevention, recognition, flexibility, aesthetics	Usability: learnability, performance, effectiveness, error tolerance and recovery, user satisfaction
	Help system	Tutorials, FAQs, troubleshooting, hypertext-based documentation, etc	Content, Structure, Appearance, Dynamics and adaptivity	
	Interaction	Speech interface, handwriting, etc	User needs, Privacy, Ownership, Context of use (environment and activity)	

means limited ability for scrolling, possible use with only one hand available, possible need for use in 'silent' mode and possible need for synchronization. Especially when the mobile application is for young children, the designer needs to remember their limited skills in hand-eye coordination and in the manipulation of small objects. Example interaction techniques make use of speech, handwriting, haptics, etc.

An important step in the design of mobile learning applications, as in any other type of application, is the continuous evaluation and re-design. Figure 2 illustrates the dimensions towards which mobile learning systems need to be evaluated, in correspondence to the design dimensions. The outcomes of the learning activity need to be evaluated against preset educational objectives, using appropriate evaluation instruments (questionnaires, quiz, drill-and-practice, etc.). The evaluation needs to compare the performance of the learner(s) before and after the mobile learning activity; and also the performance of the learner(s) who used the mobile learning application against other learner(s) who did not use it. The infrastructure network needs to be evaluated for its reliability, security, quality of service and seamlessness. The hardware needs to be evaluated with regard to ergonomics issues, including comfortable use (appropriate form, size, etc.) during the supported activities in the specified context of use, and also with regard to robustness, performance, reliability, unobtrusiveness and, in the case of sensors and probes, accuracy. The software needs to be evaluated with regard to its usability and more specifically its learnability, performance, effectiveness, error tolerance and recovery, and user satisfaction.

Table 2 summarizes the above design issues for mobile learning.

5 Conclusions

Mobile learning is an important area for research and development, as it offers new forms of communication, collaboration and learning that were not possible a few years ago. Mobile technologies have become widely available and affordable only in the recent years, therefore few commercial educational applications are currently available. We can expect rapid developments in mobile learning as the technology offers greater range at lower prices.

This paper discusses some issues that designers of mobile learning experiences need to take into account when making design choices - most of them being rather technological. However, apart from the technological issues, the full exploitation of mobile technologies, especially from a pedagogical point of view, requires a sound theoretical basis which is rather not available today: as Falk and Dierking argue, "most of what is known about learning is based on studies from either classrooms or psychology laboratories, and so may be inappropriate as a basis for considering learning outside of these settings" [11]. This is clearly not in line with the new opportunities offered by mobile technologies, therefore new learning theories and instructional models may need to be developed, which can form the educational and social basis for the delivery of effective mobile learning experiences.

References

1. Tough, A.: The Adult's Learning Projects: a Fresh Approach to Theory and Practice in Adult Learning. Toronto: Ontario Institute for Studies in Education (1971).
2. Nichani, M.: LCMS = LMS + CMS [RLOs]. elearningpost (2001) Electronically available at http://www.elearningpost.com/features/archives/001022.asp.
3. O'Malley, C., Vavoula, G., Glew, J., Taylor, J., Sharples, M., Lefrere, P.: Guidelines for Learning, Teaching and Tutoring in a Mobile Environment. MOBIlearn Project Deliverable D4.1 (2003).
4. Gay, G., Rieger, R., Bennington, T.: Using Mobile Computing to Enhance Field Study: In Proceedings International Conference on Computer-Supported Collaborative Learning, Boulder, CO, USA (2002).
5. Naismith, L., Lonsdale, P., Vavoula, G., Sharples, M.: Literature Review in Mobile Technologies and Learning, NESTA FutureLab Report (2005).
6. Savill-Smith, C., Kent, P.: The Use of Palmtop Computers for Learning: A Review of the Literature. Learning and Skills Development Agency Research Report (2003).
7. Dempsey, M.: Indoor Positioning Systems in Healthcare: a basic overview of technologies. Radianse Inc White Paper (2003).
8. Rudman, P. Sensing the world – what's 'sensable'. Electronically available at http://www.dcs.gla.ac.uk/~rudmanp/Documents/Sensable.pdf
9. Lonsdale, P., Baber, C., Sharples, M., Byrne, W., Arvanitis, T., Brundell, P., and Beale, H. Context awareness for MOBIlearn: creating an engaging learning experience in an art museum. In Proceedings of MLEARN 2004, Bracciano, Rome, LSDA (2004).
10. Neisen, J.: Usability Heuristic Evaluation. In Nielsen, J., Mack, R.L. (Eds.). Usability Inspection Methods. John Wiley & Sons, New York, NY (1994).
11. Falk, J., Dierking L.: Lessons Without Limit: How Free-Choice Learning is Transforming Education. AltaMira Press (2002).